MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

Vol. 50 No. 7.
W. B. No. 781.

JULY, 1922.

Closed September 2, 1922
Issued October 2, 1922

THE SEMIPERMANENT ARIZONA LOW.

By E. A. Beals.

[Weather Bureau, San Francisco, Calif.]

Although there is a rainy and a wet season in the Pacific States, it is sometimes fair in winter and sometimes it rains in summer. It is the good weather in winter and the bad weather in summer that are so hard to predict, and I believe better work in forecasting summer rains would result from a better understanding of the action of the air over the interior of California and Arizona during the summer months.

In the book entitled "Weather Forecasting in the United States," written by officials of the Weather Bureau and published in 1916, I called attention to the Great California Valley as the place of origin of low-pressure areas that produce some of the summer rains in the North Pacific States. It is my opinion that this center of activity has not been given the study it deserves in forecasting work.

Among the effects of heated air over a definite land area mentioned as being the cause of rainfall is one by Griffith Taylor, who is attached to the Commonwealth Weather Service of Australia. He states:

> The regions of greatest convection are logically more likely to control the supply of lows and of rainfall and storms than the so-called "centers of action."

Mr. Taylor's explanation of his theory can be found in Chapter XVIII of his book entitled "Australian Meteorology," published in 1920. He mentions two convective centers of action in Australia, one in the west-central portion of the State and the other near the north-central portion.

He states:

> Over such centers [of action] * * * there is built up a column or dome of warm ascending turbulent air. * * * The building up of this "dome" increases day by day, until it becomes, as it were, top-heavy. Thereupon an eddy of air buds off—much as the satellites leave the parent—and sails away in the current of upper air drift, which is usually to the east. * * * The chief rains are associated with the satellite lows, which bud off and move to the southeast.

I am in thorough agreement with him in what he calls "the convection-dome hypothesis," whereby it is assumed that strong convection over heated areas produces eddies that later develop into storms of sufficient energy to cause rain; but the Aleutian low-pressure area is, nevertheless, the dominating factor in generating winter storms that affect the Pacific coast of the United States.

However, a number of the storms causing summer rains in the Pacific and Rocky Mountain States, according to my belief, originate over the valley of the lower Colorado River and the great interior Valley of California. The low-pressure areas that have their genesis in this region sometimes move east and cause rains in the Middle West and Eastern States, therefore they are of more than local importance in consequence of their far-reaching effects.

More rain falls from these low-pressure areas in the Pacific and Rocky Mountain States than is shown on the weather map, as all stations reporting by telegraph are located either along the coast, on plateaus, or in valleys, whereas the rainfall is heaviest in the mountains, where there are no stations reporting daily by telegraph.

I myself have seen a cumulus cloud form over an intense conflagration. The base of this cloud was so dense as to indicate that rain might fall from it at any moment. This fire was in a lumber yard covering about an acre of ground, and the cloud was estimated to be about 1,500 meters in height. If intense heat over such a limited area will produce a cloud, a less degree of heat over a larger area might generate eddies in the atmosphere that would develop into low-pressure areas of sufficient intensity to produce rain.

It is asserted that upwelling cold waters in the Pacific Ocean just west of California mark the eastern extension of a so-called permanent high-pressure area. From this high-pressure area come cold northwesterly surface winds of high humidity, so much so that the California coast is bathed in fog during the greater portion of the summer months.

In contrast to this the interior valleys of California and lower Colorado valleys experience temperatures for days at a time above the 100° mark. To the east of these valleys the prevailing summer surface winds are southerly with low humidity.

Thus the conditions are ideal for the formation of eddies in the air adjacent to the Sierra Nevada Mountains, and the only element needed for a full-fledged storm is plenty of moisture. This is usually deficient because the air coming from the ocean is cold, and though loaded to its capacity with moisture can not easily again become saturated when mixed with warmer and drier air till cooled below the dew point by expansion at high elevations.

As a rule eddies that form over the California and lower Colorado valleys do not produce rain until through convection they have accumulated sufficient moisture for this purpose. This they do to a greater extent after moving some distance to the north or east of the place where they are formed.

The charts displayed and marked A, B, C, etc. (figs. 1–2), illustrate the formation and movement of the eddies that apparently separate from the dome of rising air over the California and lower Colorado valleys as a result of a spell of hot weather that began on July 3, 1920. Before examining this specific case, a few general remarks on the subject will perhaps put the matter in a clearer light.

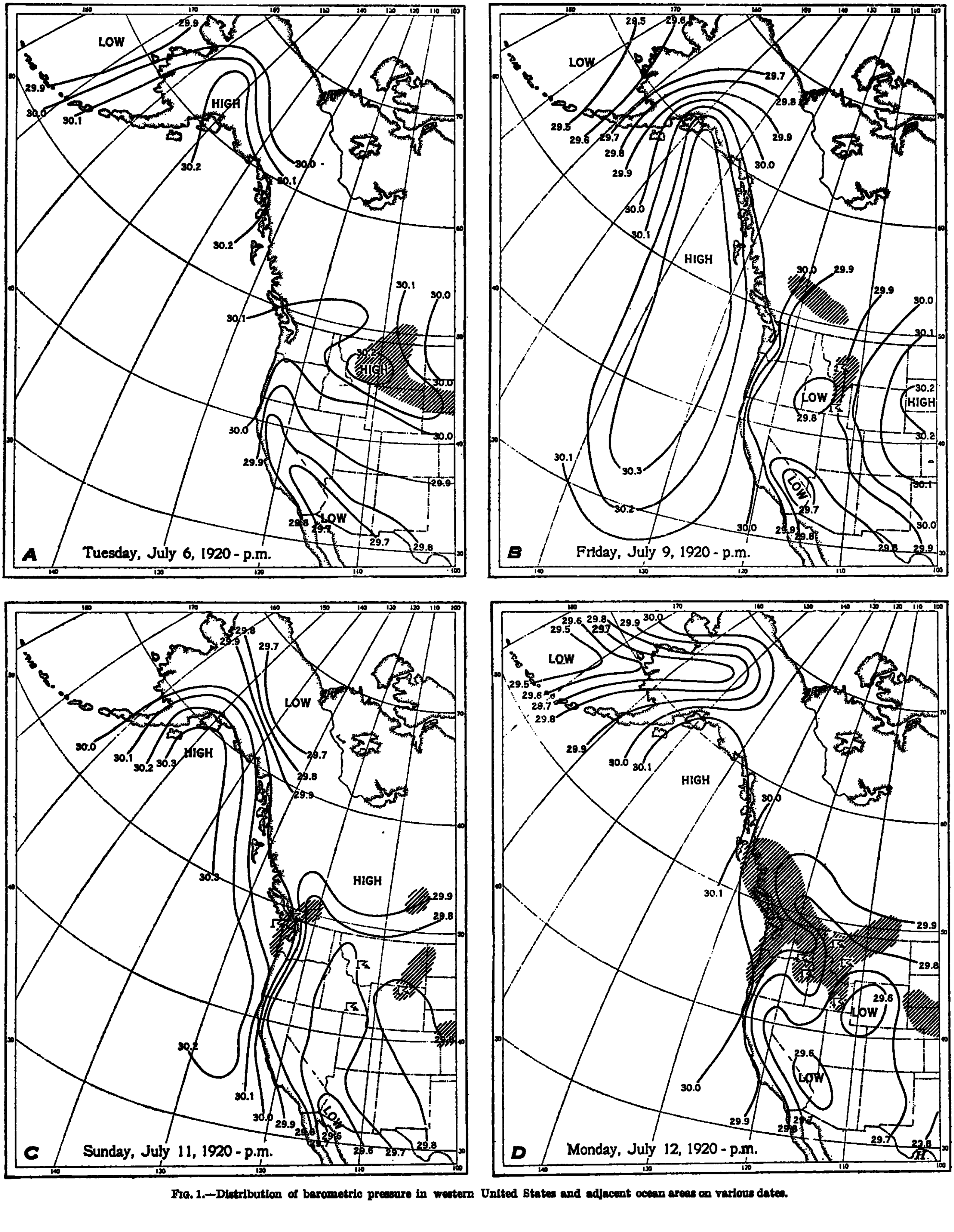

FIG. 1.—Distribution of barometric pressure in western United States and adjacent ocean areas on various dates.

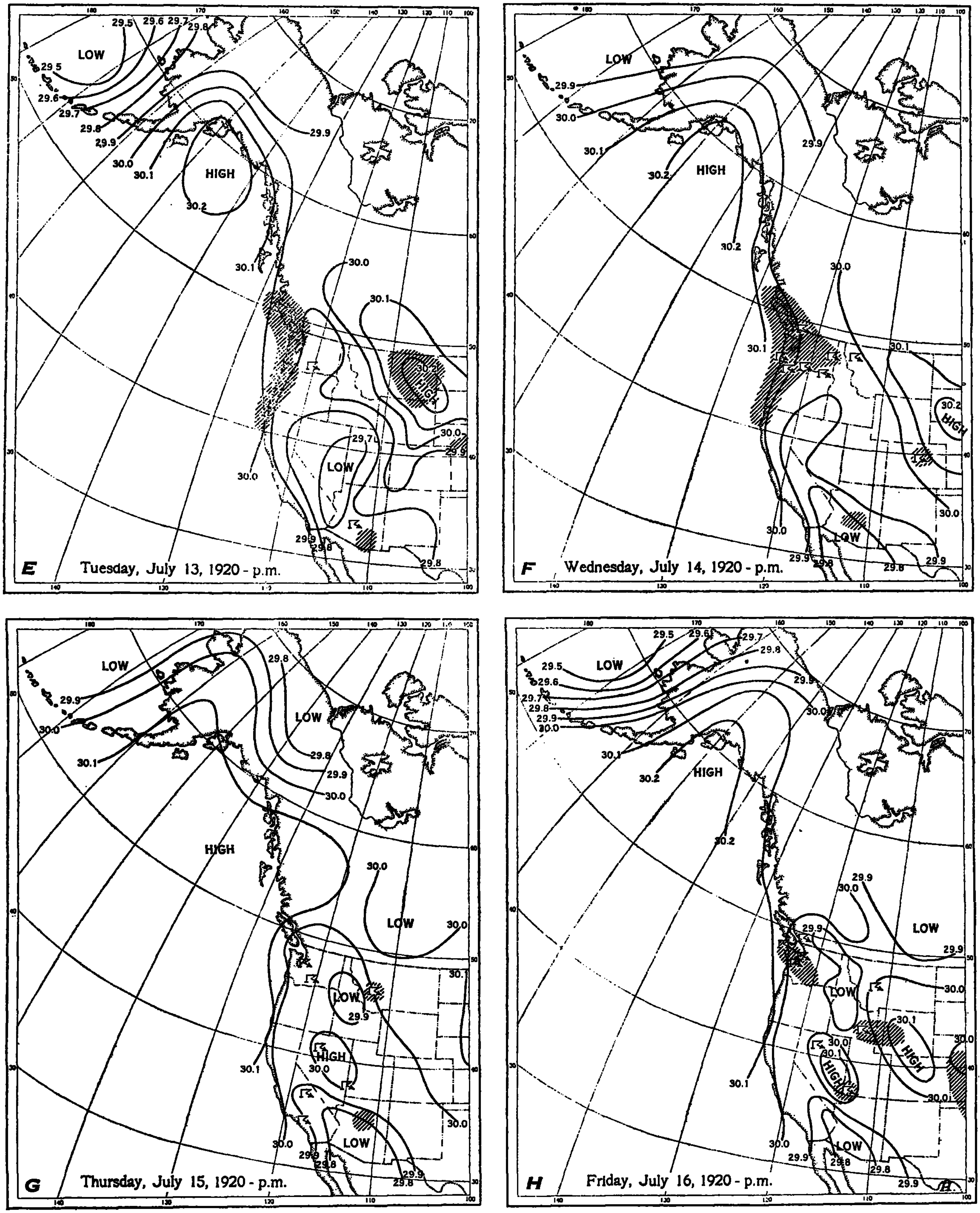

FIG. 2.—Distribution of barometric pressure in western United States and adjacent ocean areas on various dates.

It is my opinion that the summer movements of high-pressure and low-pressure areas in the western portion of the United States are controlled by the so-called permanent high-pressure area over the North Pacific Ocean, which impinges at times on the North Pacific coast, and the dome of warm, ascending, turbulent air over the California and lower Colorado valleys.

First, is a hot spell in California, and consequently warm, ascending air, that either drifts north, northeast, or eastward, but most often northward. When it drifts northward one or more secondary low-pressure areas form before its northward limits are reached, after which they move eastward to the upper Mississippi Valley, or to the Lake region, where they dissipate. During the time they are moving northward they nearly always are connected by a stream line, with the original low-pressure area over California and Arizona. The secondaries, which later form independent low-pressure areas, cause rain in their passage eastward, but more especially in the upper Mississippi Valley. After a secondary forms into an independent low-pressure area and moves east, a portion of the North Pacific high-pressure area becomes detached from the original oceanic high-pressure area and follows it to the upper Mississippi Valley. The high-pressure area then moves southeastward and joins the Atlantic high-pressure area, or an extension of the same, overlying the South Atlantic States. As soon as a small high-pressure area breaks loose from the North Pacific oceanic high-pressure area and begins to move eastward, another low-pressure area separates from the dome of ascending air over California and Arizona and moves north, to repeat the process of moving east and causing rain in the northern States between the Rocky Mountains and the Lake region.

Sometimes a low-pressure area thus separates from the Arizona dome of rising air and drifts eastward. In these cases the secondary, which usually forms over the Central Plains States, generally becomes more energetic and lives long enough to pass down the St. Lawrence Valley. In doing so it gives abundant rain from the central Mississippi Valley to the Atlantic coast. Low-pressure areas that separate from the Arizona dome of rising air and move eastward are usually prevented from moving north by the presence at that time of a large high-pressure area over the North Pacific States. The northward movement, I believe, is the favorite one for them to take, other things being equal.

The low-pressure areas in moving eastward sometimes increase and sometimes decrease in energy, in accordance with the abundance or deficiency of their supply of heat and moisture. The high-pressure area may also increase or decrease in magnitude.

Quite a number of low-pressure areas that separate from the dome of rising air over California and move north to British Columbia do so in connection with a low-pressure area formed over Alaska, which moves southeastward to British Columbia. In these cases the low-pressure area over British Columbia is reinforced by the California accession of warm air and a storm of considerable energy is generated which gives abundant rains from coast to coast.

These storms are most frequent during the transition period between summer and winter and again between winter and summer, as at these seasons there is still sufficient energy in the Bering Sea center of action to send out offshoots. In midsummer the Bering Sea center of action is unimportant, and practically the only rains visiting the Pacific States at this season of the year comes from eddies that arise from the dome of ascending air over California and move northward. These eddies cause but little rain in the San Francisco forecast district, but they are attended by frequent thunder and lightning in the mountains. The lightning from them causes many forest fires in the Pacific and Rocky Mountain States, some of which, on account of their inaccessibility, do a great deal of damage before being put out.

On chart A are shown the isobars over the United States, western Canada, and Alaska on July 6, 1920, at 8 p. m., 75th meridian time, except the observations at the Alaskan stations were taken at 8 p. m., 135th meridian time. For three days previously the temperature had been rising steadily in central California. On the 4th the increase amounted to 10°, on the 5th to 5°, and on the 6th to about 5°, making altogether a rise of 20° for the three days. During this period and for some time previously temperatures were above the 100° mark in the lower Colorado Valley.

At the time represented by Chart A (fig. 1) there was a low-pressure area over the upper Lake region, which was connected by a trough with the low-pressure area over southwestern Arizona. It is difficult to identify on the charts the previous movement of the low-pressure area over the upper Lake region, but presumably it originated about July 1 over southwestern Arizona and southern California, where an eddy formed which moved north to Saskatchewan, which place was reached the morning of July 3. This Saskatchewan low-pressure area then moved southeastward to western South Dakota, where it greatly diminished in intensity; but, by the morning of the 5th, it was reinforced by the Arizona low-pressure area and 36 hours later it was a full-fledged storm over the upper Lake region. It eventually moved down the St. Lawrence Valley and gave good rains in all of the northern States east of the Mississippi River.

The features on this chart to which attention is called is the existing low pressure over southwestern Arizona and California, with its extension north to Washington and thence eastward to Calgary. This is the type that marks the beginning of the separation of an eddy from the dome of the turbulent rising air over the heated valleys of California and the lower Colorado River. No material change took place in this distribution of pressure during the next three days, except that pressure over California northward gradually fell as the high-pressure area moved slowly southeastward and spread over a much larger territory. No rain up to this time had fallen anywhere in the San Francisco forecast district.

The evening chart of July 9, 1920, is marked B, and it shows the formation of a secondary low-pressure area over Boise, Idaho, and an increase in the size of the high-pressure area over the Plains States. A thunderstorm occurred at Salt Lake City. Note also the position and size of the great high-pressure area off the Pacific coast and the further fact that there is no offshoot from the Bering Sea low-pressure area in evidence.

No chart has been drawn to illustrate the conditions on the 10th, as no marked changes occurred. The barometric pressure decreased slightly over the Canadian Northwest, the high-pressure area moved farther east and a thunderstorm occurred at Helena.

The chart for July 11 is marked C, and it shows the high-pressure area off the coast is undiminished, the trough to the northward is farther east than before, and relatively high pressure prevails over the Canadian Northwest. By this time rain is becoming more general and thunderstorms have occurred in the northern Rocky Mountains and also in northwestern Washington and at a few places in British Columbia. The movement of the trough eastward caused a drop of about 7° or 8° in temperature in the interior of California, while the Arizona temperature remained as high as ever.

Chart D shows the conditions the next day, July 12, and here we have more rain in the North Pacific States and British Columbia, most of which is attended by thunderstorms. The high-pressure area off the Pacific coast has apparently lost energy, and the secondary over southern Idaho has reappeared. There is also evidence of a storm developing over the Bering Sea which may complicate matters should it move southeastward.

On the 13th the conditions are shown on Chart E (fig. 2) and here is seen a development of the high-pressure area which was faintly indicated on Chart C. The low-pressure area over Bering Sea is less pronounced and the consolidation of the southern Idaho low-pressure area with the original low-pressure area over Arizona has taken place. The rain has diminished and most of it fell locally along the North Pacific coast.

The next day, July 14, is represented on Chart F, which is somewhat like Chart A; but with this difference, the barometer is lower in the north and rainfall, which was lacking on Chart A, is quite abundant along the North Pacific coast. Thunderstorms have occurred at Yakima, Spokane, and Kalispell. Temperatures in the interior of California have risen about 8° in consequence of the rearrangement of pressure.

The conditions on the 15th are shown on Chart G, and here is seen a secondary over Idaho, with relatively low pressure over the Canadian Northwest. The high-pressure area has moved east, and the high-pressure area over the ocean is about the same as it was for the last few days. So few reports from the ocean are available that this high-pressure area can not always be definitely located. The rains are light and sporadic. Thunderstorms occurred in the southern portion of California and also at Winnemucca and at Seattle.

The final chart, marked H, shows a general unsettled condition over the Pacific States. Rain has fallen quite generally in Nevada, northern Washington, and western Montana. The eastern high-pressure area is disintegrating, and the relatively low pressure of the day before over the Canadian Northwest has recovered somewhat. This low-pressure area two days later reached the upper Mississippi Valley, and still later passed down the St. Lawrence Valley. In doing so it caused showery conditions in the Lake region and in the North Atlantic States.

Nothing would be accomplished by showing more charts, for they are continually repeating themselves with slight variations all summer long. They give an excellent idea of the difficulties encountered in predicting rain during the summer months in the Pacific States. During the period from July 11 to 16, inclusive, rain fell in nearly all portions of the San Francisco forecast district, and it was evident that it would do so. However, to place this rain geographically for 12-hour intervals was an entirely different matter, and the only thing possible was to make an indefinite forecast for places where it was thought the rain was mostly likely to occur.

Reports from Mexico and a greater number of upper-air observations would undoubtedly be of help in obtaining more definite information regarding the mechanism of the offshoots from what I believe should be called the semipermanent Arizona low. The California part, which first attracted my attention, now seems to be an auxiliary that probably has something to do with directing the movement of the stream lines, or eddies, northward. By taking the northward course they receive additional heat as well as a greater supply of moisture than would be the case if they moved to the northeast or to the east.

DISCUSSION.

By E. H. BOWIE.

With regard to the quotation from Griffith Taylor in the opening of Mr. Beals's article, I would remark that my understanding of this matter is that it has been presented to us quite fully by the late Professor Ferrel in his discussion of the formation of cyclones; in the minds of some, however, convection does not account for the formation of cyclones but has to do with the origin of showers and thunderstorms as observed in the Tropics and other parts of the world.

Doubtless many meteorologists will take exception to the view that in overheated, arid areas there is built up a column, or dome, of warm, ascending, turbulent air as suggested by Taylor. The English idea, if I may so call it, is to the effect that air rises in threadlike streams, not *en masse*, and that between these threadlike streams there will be areas over which air is descending. Hence the sporadic character of thundershowers in regions of strong convection, such as the southeastern part of the United States.

Certainly if heat alone would produce cyclones there should be a considerable number over the far Southwest during the summer, but such is not the case as may be easily seen by reference to MONTHLY WEATHER REVIEW SUPPLEMENT No. 1, Types of Storms of the United States, by Bowie and Weightman. This report shows that for the months of June to September, inclusive, in 21 years but 30 cyclones moved out of the area under discussion, or a little more than 2 per year.

DISCUSSION.

By W. J. HUMPHREYS.

The description of the development of cyclonic storms in the region of southwestern Arizona is both interesting and useful.

It may be remarked with reference to the trough of low pressure which appears to be largely induced by the high temperature of the Arizona and California valleys, that such trough, as indeed all troughs, is unstable and likely to break up into isolated lows or secondaries. This is especially true when the trough is well developed or flanked by a high to the west and another to the east with oppositely directed winds on its two sides.[1]

If there is no precipitation, such a low (secondary) probably will soon be dissipated. With precipitation it may persist for some time and over long distances.

DISCUSSION.

By A. J. HENRY.

Before entering upon a discussion of Mr. Beals's paper it would be helpful to state briefly the several aspects of the paper upon which there is general accord.

Although the author does not specifically state the number of cyclones of the type described he has considered, I think we can accept the count given in Supervising Forecaster Bowie's statement, viz, about 2 per year (in summer).

[1] While this situation may and does arise in the cold season it would fail in the warm months, since high-pressure areas at that time of year seldom, if ever, extend as far south as the lower margin of the Great Basin in Nevada.—EDITOR.